The Continued Development of the Third-generation Shallow Water Wave Model "Swan"

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LONG-TERM GOAL

The long-term goal of this effort is to provide a commonly accepted third-generation wave model for shallow water to the international community of scientists and engineers for the purpose of basic research and operational wave computations (public agencies such as army, navy, harbor authorities, universities and private industry such as oil companies, engineering companies, etc.).

OBJECTIVES

The main objective is to support and assist the continued development, validation and verification of the SWAN model and its use in operational conditions. The development will be based on new scientific insights in the evolution of waves in shallow water. The verification and validation will be based on field observations and laboratory experiments supplemented with numerical experiments. Operational use will be supported with first-line assistance and diagnostics.

APPROACH

The continued development of the SWAN model is envisioned as a community effort of the wave modelers presently working in this field of technology, most of whom coordinate their efforts in an international forum called the WISE group (Waves in Shallow Environments, established in 1993 as the shallow-water follow-up of the WAM group and the HISWA group).

We provide support and assistance to these ONR-designated investigators. We assist in the installation of SWAN under conventional operating systems (also as a sub-model in larger systems of models such as atmospheric and ocean circulation models). The present extensive and detailed documentation (about 100 pages) is being supplemented with introductory documentation. Questions of users are answered and errors are located and repaired (often in response to problems encountered by the users). Updated program codes (including new cycles) are communicated to all registered users. This support is operating through electronic-mail facilities.

We are collaborating with ONR-designated investigators to improve the model technology of SWAN. We will independently add wave reflections (including scattering) to the model for sub-grid elements (e.g. breakwaters) and coastlines.

This approach is essentially a continuation of the development of the SWAN model over the years 1992 - 1996 by J.A. Battjes, L.H. Holthuijsen and N. Booij and their Ph.D. students. This consists of designing, implementing and testing a fully spectral third-generation wave model for shallow water with a fully implicit propagation scheme. Battjes supervises the scientific developments, Booij supervises the numerical developments. Holthuijsen is responsible for project management and overall supervision. In addition, IJ. Haagsma carries out the upgrading of the computer code as regards system requirements and provides first-line support for the users. A. Kieftenburg carries out the upgrading of the computer code as regards scientific and numerical aspects and she shares the first-line support with Haagsma.

WORK COMPLETED

Support and assistance

Installation, nesting and linkage:

a) A new version of SWAN (40.01) was released on 29-9-1999. This version has been tested, using improved bench mark tests (see below). New features in SWAN are:
    - It permits prescription of non-stationary boundary conditions.
    - It has a new format for spectral input and output files.
    - It permits the output of the source terms in spectral format.
    - It permits the calculation of wave induced set-up (1D and 2D).
    - It permits user defined initial conditions.
    - It permits non-stationary calculations, also in 1D mode.
    - It permits the user to combine stationary and non-stationary computations.
    - It permits the user to interrupt the computation.

b) The SWAN homepage on the internet has been reconstructed and regularly updated. It now contains links to the webpages of related models, and discussion groups for several topics. The latter are meant as a means of communication and discussion between users.

c) The old version of SWAN (30.75), which was available since April 2, 1998 until September 28th 1999, was downloaded by approximately 220 institutes from 45 countries.

d) In the report period 132 queries of users about SWAN installation have been answered: general information (37), program bugs (16), installation (28), code (16) and usage (35).

e) The testing of the SWAN code with the Lahey Compiler version 4.0 (severest level) was continued.

f) The performance of SWAN has been tested on a Cray J90 vector computer. This has lead to a few minor improvements.

g) Conversion programs to convert the spectral information from and to the new spectral format are provided.

User documentation:

a) The user manual has been updated to fit the new version of SWAN. An index has been added to this manual. This manual is available in Word Perfect 8, Post Script and Portable Document Format.

b) A short version of the user manual of SWAN has also been released. It is generated by suppressing detailed information in the regular user manual. This manual is available in Word Perfect 8, Post Script and Portable Document Format.

c) The implementation manual has been updated. It is available in Word Perfect 8, Post Script and Portable Document Format.

d) Several subroutines have been adapted to the SWAN coding protocol.

e) A user discussion group on the SWAN home page has been added to the SWAN home page. It will allow SWAN users to communicate in several categories of questions and answers.

f) A configuration group for SWAN to advise the SWAN steering group on requirements for system configuration of SWAN is under discussion.

User support, diagnostics and repairs:

a) All known coding bugs from SWAN 30.75 have been fixed in SWAN 40.01 (one new bug has recently been discovered).

b) The updating of the system documentation (headers of the subroutines) has continued.

c) A pilot study for an extended suite of bench mark test with a HTML interface was carried out by Alkyon Research (funded by Rijkswaterstaat). Finally a batch-mode version, based on SWAN 40.01, has been developed by WL|Delft Hydraulics with the support of Delft University.

d) Registration of users now is done automatically through the SWAN home page. Registration data is automatically stored in a data base.

e) One type of compiler warning (with a very large number of occurrences) has been avoided by using an EQUIVALENCE statement to modify the type declaration of variables in SWAN 40.01.

Improvement of model technology

a) The option of computing wave-induced set-up in two-dimensional mode has been implemented in the new version of SWAN. It is exact in 1D cases and approximate in 2D cases.

b) The numerical estimation of the fraction of breakers in the surf zone has been made more accurate.

c) When triad interactions are active, the quadruplet interactions and the limiter are deactivated. The effect is that the limiter no longer unduly dampens the triad wave-wave interactions. The coefficients of the triad interactions have been given corresponding new default values.

d) Convergence of SWAN in stationary mode has been studied by Delft University, WL|Delft Hydraulics, Alkyon Research and Rijkswaterstaat, with the aim to improve the convergence rate for cases with high wind speeds. The study resulted in an adapted first guess (in stationary mode). In this first guess the directional spreading of the spectrum is somewhat larger and it is driven by the friction velocity U_* instead of U_{10} .

e) The break- off criteria for the iterative procedure have been changed.

f) The curvi-linear grid capability of SWAN has been tested (by Delft Hydraulics, funded by Rijkswaterstaat). The tests show that the curvi-linear grid capability of SWAN has been implemented correctly.

g) SWAN has been implemented for DUCK (USA) and DELILAH cases have been tested (M.Sc. thesis work). Results seem to indicate that a steepness-dependent breaking coefficient performs better than the existing formulation, and that the triad interaction, formulated on the lumped triad approximation needs improvement (other than mentioned under c).

h) A study on the modifications of the whitecapping source term has been initiated. This work is carried out by Delft University of Technology jointly with WL|Delft Hydraulics, funded by Rijkswaterstaat.

i) Implementation in SWAN of the method to calculate quadruplets by Resio and Tracy is currently carried out in cooperation with Alkyon Research (funded under another BE program).

j) The third-order propagation scheme in SWAN for essentially nonstationary cases (due to G. Stelling of Delft University; implemented and tested by Rogers, Kaihatu and Booij; funded under another BE program) has been slightly modified and it has been implemented in an experimental version of SWAN (to be released next year after extensive testing). The stationary version of the (slightly adapted) scheme has also been implemented and tested by the same authors in an experimental SWAN version. Possibilities are studied to make the stationary third order scheme less inefficient. Provisions have been made to avoid the garden sprinkler effect

k) Spherical coordinates have been implemented in an experimental version of the new SWAN, and are being tested.

RESULTS

The significance of the above completed work is that the most advanced wave model to date for coastal applications (horizontal scales with a maximum of 25 km, and water depth with a maximum of 20 m) has been made available free of charge to the international community of scientists and engineers. In this third year approximately 250 institutes from all over the world are using the SWAN program.

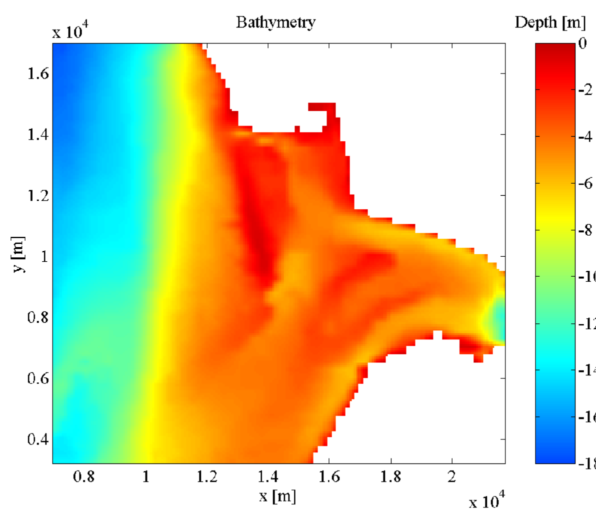

Fig.1 Bathymetry of the Haringvliet (The Netherlands)

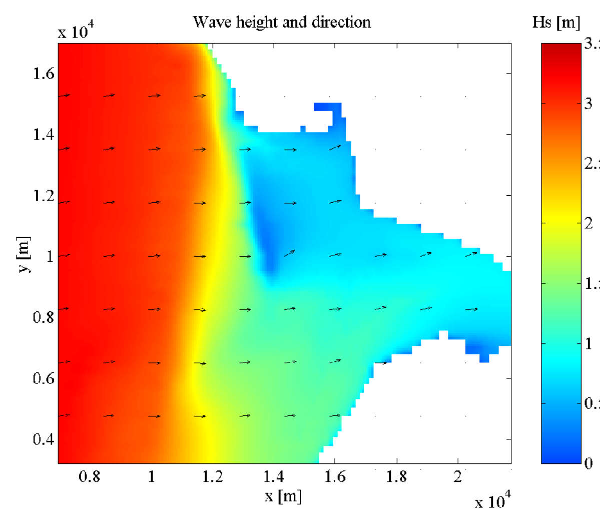

Fig.2 Significant wave height and wave direction in the Haringvliet (The Netherlands)

As an example of one new capability of SWAN (40.01) the results of the new 2D set-up are illustrated here for the Haringvliet (the Netherlands): the bathymetry is shown in Figure 1; the calculated significant wave height and wave direction, given a 3.22 m boundary condition at the ‘left boundary’ of the computational domain, are shown in Figure 2 . The calculated set-up is shown in Figure 3 with a maximum of about 0.15 m and a minimum (set-down) of about 0.02 m (at about x = 10,000 to 12,000 m).

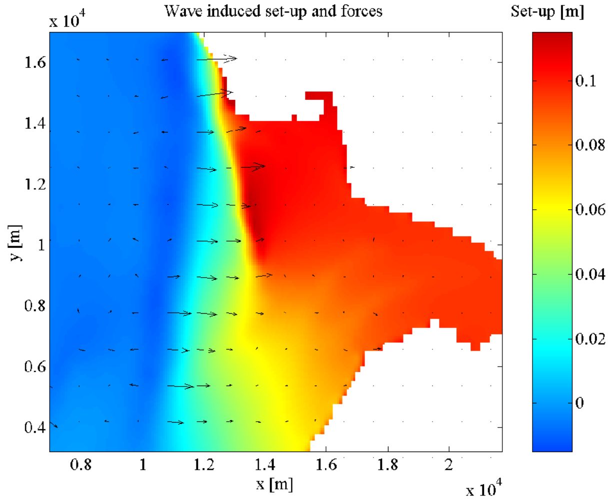

Fig.3 Wave induced set-up and forces in the Haringvliet (The Netherlands)

IMPACT/APPLICATION

SWAN provides scientists with a common platform for their research of the generation, propagation and dissipation of wind surface waves in shallow water. The community SWAN model facilitates the integration of these aspects and avoids the need to develop supplementary models in each individual research project. Moreover, with the support provided here, the results of such projects will be implemented in a fully operational cycle of the SWAN model thus serving the community in general (for this purpose the SWAN model is freely available for active members of the WISE group). It therefore also provides a common standard for engineering applications accepted by a large number of institutions worldwide.

TRANSITIONS

The SWAN model is available free of charge to anyone (essentially in the public domain). It can be downloaded from the SWAN homepage. Its use is supported by the original authors under this project. SWAN is aimed at operational use by such government agencies as army and navy, national weather services and others, in the USA and abroad. Also private industry is using SWAN, mostly to determine the coastal wave climate for the purpose of design of structures and off-shore operations.

RELATED PROJECTS

Considerable efforts are being carried out by others to further develop the SWAN model. In the USA this is coordinated mostly through the DRI and BE programs of ONR. In Europe, similar efforts (on a smaller scale) are carried out by groups of investigators funded by the EC and by national governments (notably in the Netherlands, Germany and England). The nature of these efforts is both theoretical and empirical and require extensive field work and computer experiments. The level of funding is several million US dollars per year.

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